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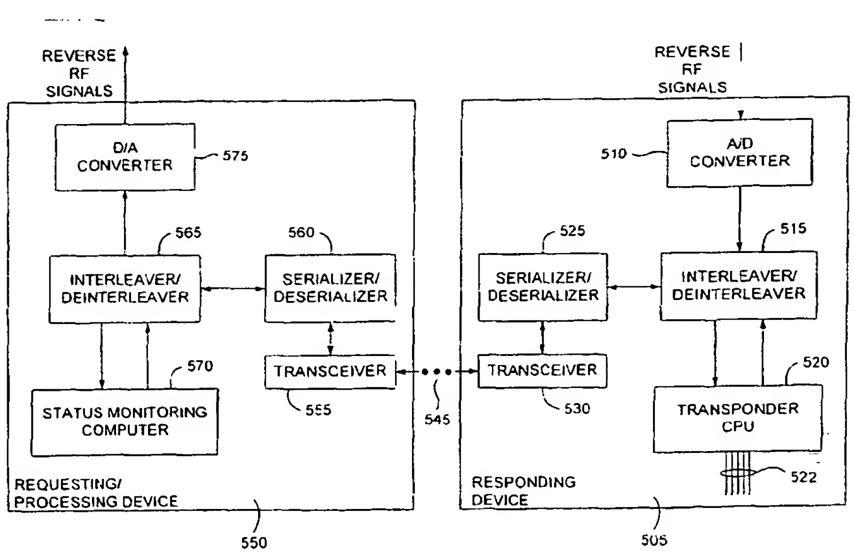
(54) Title: DIGITAL STATUS CHANNEL FOR BROADBAND COMMUNICATION SYSTEM



(57) Abstract: A broadband communication system (FIG. 1) having a reverse path over which reverse, upstream signals are transmitted and forward path over which forward, downstream signals are transmitted includes a requesting device (345) for generating and transmitting a downstream digital optical signal comprising a status request and information. The system also includes a responding device (410) coupled to the requesting device (345) for receiving the downstream digital optical signal and decoding the status request therefrom. The responding device (410) also processes the status request in its digital format and gathers digital inputs indicative of requested statuses. Then, the responding device (410) transmits an upstream digital optical signal, comprising at least status information indicative of the requested statuses, to the requesting device (345) over an optical communication channel.

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DIGITAL STATUS CHANNEL FOR BROADBAND COMMUNICATION SYSTEM

FIELD OF THE INVENTION

This invention relates generally to broadband communication systems and, more specifically, to methods and systems for monitoring the condition of components within such communication systems.

BACKGROUND OF THE INVENTION

Broadband communication systems, such as cable television systems, typically include a control center, or headend station, that serves as an interface between the communication distribution network and satellite transmission systems that distribute conventional cable television programming. In the forward, or downstream, direction, the headend station receives information from the satellite systems and converts it to a suitable format for optical transmission to downstream elements of the cable distribution system. In the reverse direction, it may receive a multiplexed optical information signal from a number of subscriber locations, and then demodulate it for further processing.

Depending on the size of the distribution system, the optical signal from the headend station may be transmitted directly to a node that functions as an optical-to-radio-frequency (RF) transceiver or to primary and secondary hubs that amplify and distribute the signal. RF signals leaving the node are distributed to individual subscribers using a network of amplifiers and taps.

In the reverse, or upstream, direction, the same system routes RF information from individual subscribers to the node, where the information is converted from an electrical signal to an optical signal that is transmitted along fiber optic lines to the primary hub/headend station. In most situations, the reverse signal is transmitted at frequencies below 50 MHz.

Transmission in the reverse direction is complicated by the strength and number of noise sources in the designated frequency band. In addition, noise from a large number of subscribers is combined at the RF input to the node. In order to address these issues, an amplitude modulated (AM) format is conventionally used.

In addition to information transmission to and from the subscriber, a typical cable communications system is also capable of monitoring the status of key plant components. This function is typically performed by a status-monitoring computer that is located at the primary hub/headend station and that communicates with transponders located at nodes and hubs throughout the system. The transponders are connected to network elements and can detect, for example, power supply problems, laser failure, and excessive temperature excursions in addition to some problems with transmitter and receiver performance. In operation, the status-monitoring computer sends a signal that polls an individual transponder. When the polling signal is received, the transponder transmits its status information back to the primary node/headend, where the status information is processed by the status-monitoring computer.

In a conventional cable system, the polling signals are transmitted to nodes distributed throughout the system using a lightwave carrier that is amplitude-modulated according to known techniques. At an individual node, a transponder demodulates the polling signal and routes it to a small computer that is responsible for monitoring the status of several key parameters that affect node performance. When the appropriate information has been gathered by the transponder, the performance data, i.e., the status information, is transmitted back to the headend station. Conventionally, a radio-frequency (RF) modulator within the transponder converts the digital electrical data to an appropriate AM modulation format for transmission back to the headend station from the node.

While AM modulation techniques were appropriate for conventional cable television systems, the industry trend is towards transmission of digital data in both the forward and reverse directions. Thus, what is needed is an improved method and system for monitoring component status that is compatible with and takes full advantage of new digital architectures.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGs. 1 and 2 are block diagrams of conventional communication and status monitoring systems.

FIG. 3 is a block diagram of a communication path in which the status monitoring system in accordance with the present invention can be employed.

FIG. 4 is a block diagram of a responding device, such as a node, for transmitting status information within the status monitoring system in accordance with the present invention.

FIG. 5 is a block diagram of an information processing device, such as a headend or hub, for receiving and processing status information within the status monitoring system in accordance with the present invention.

FIG. 6 is a block diagram of an alternative status monitoring system in accordance with the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 shows an analog cable television distribution system according to the prior art. In this system, a headend station 100 receives program information from a satellite system 105 (a satellite transmission, for example) and retransmits it as an optical signal to one or more nodes 110 via an optical communication medium 115. In alternative architectures, primary and secondary hubs may be inserted between the headend station 100 and any nodes 110 in order to serve a larger subscriber base. The node 110 converts the optical signal received from the headend station 100 to a radio frequency (RF) signal that is transmitted to individual subscribers 135 through a network of coaxial cable lines 120, RF amplifiers 125, and taps 130.

In order to provide pay-per-view programming and similar services, nodes 110 are typically equipped with RF receivers and optical transmitters that can send a limited amount of information back to the headend station 100 or to a primary hub that processes and/or forwards the information. The two-way distribution system between the headend station 100 and the nodes 110 is also commonly utilized to monitor the operating condition of components that are located at the nodes 110. This function is performed by a prior art status monitoring system similar to that shown schematically in FIG. 2.

FIG. 2 depicts a conventional status monitoring system that includes a status monitoring computer 150 that is located at the headend or primary hub 100 and that communicates with transponders 190 at some or all of the individual nodes 110. To determine the operating status of a particular node 110, the status monitoring computer 150 generates an address code that is transmitted throughout the system. Upon recognizing its address, an individual transponder 190 transmits node status information in the reverse direction, i.e., upstream. This information may include the ambient temperature in addition to parameters that are related to the status of the laser diode, the optical receiver, the transmitter, and other key components. By polling each node 110, such as by transmission of the address of the resident transponder 190, in the communication system on a regular basis, component failure may quickly detected and repaired.

In the prior art, data is transmitted between the primary hub and nodes using amplitude modulated light. In contrast, the outputs of transponders and any status monitoring computers are true digital signals comprising strings of binary numbers. In order for these outputs to be compatible with the other components of the conventional system, modulators 155, 210 must convert the digitally modulated computer outputs of the transponders and status monitoring computers to an amplitude modulated signal. Demodulators 160, 205 perform the inverse function.

At the primary hub or headend 100, digital data generated by the status monitoring computer 150 is converted to a modulated RF signal by the modulator 155. It is combined with program signals 250 from various sources using a directional coupler 175, and the combined signals are transmitted to the nodes 110 by the optical transmitter 170.

At the node 110, the optical signal from the headend/primary hub 100 is processed to recover the transmitted radio frequency electrical signal by the receiver 225. The receiver output is split into the status signal 255 and program signal 260 components by the directional coupler 230. The status signal 255 is then demodulated by a demodulator 205. The resulting bit stream is coupled to one of the inputs of the transponder central processing unit (CPU) 200. Other digital status inputs 265 provide data related to the condition of the transmitter 220, receiver 225, and other node components.

The transponder CPU 200 numerically processes the data from the status inputs. Upon receiving the appropriate digital address code (originally transmitted in analog

format by the headend 100 and converted to a digital format by the demodulator 205), the CPU 200 sends the node status results in a digital format to the modulator 210. The amplitude modulated output of the modulator 210 is combined with other reverse signals 270 by the directional coupler 215, and the combined signal is sent back to the headend/hub 100 by the optical transmitter 220.

At the headend 100, the combined reverse optical signal is converted to an electrical signal by the receiver 165. The directional coupler 180 forwards status information to the demodulator 160, where the status information is converted into a digital format by the demodulator 160. The resulting data is read by the status monitoring computer 150.

Conventional status monitoring systems similar to those of FIG. 2 suffer from a number of problems resulting from the use of an AM reverse link. For example, the RF output level of each receiver 165, 225 is directly dependent upon the optical modulation index (OMI), which in turn is directly related to the RF drive current, the laser threshold current, and the laser bias current of the laser located in the corresponding transmitter 170, 220. Since the laser bias and threshold currents vary with temperature, which in turn causes temperature variations of the OMI, the RF output level of the of the optical receiver also varies with temperature. In addition, the linearity of the received optical signal is directly dependent upon the linearity of the transmitting laser the receiving photodiode. Therefore, non-linearities of those devices can greatly degrade the performance of the reverse path system. Furthermore, the non-linear conversion processes of lasers and photodiodes in conventional systems vary with temperature, further degrading the performance.

As described in U.S. patent application serial no. 09/102,344 to Farhan et al., entitled "Digital Optical Transmitter" and assigned to the assignee hereof, which is hereby incorporated by reference, these issues may be effectively addressed by utilizing a digital modulation format for transmitting information from the subscriber to the node, hub, and/or headend. According to the present invention, significant improvements in the performance and cost of a status monitoring system are achieved by utilizing a digital modulation format to transmit information from node transponders to a status monitoring computer located at a primary node, hub, or headend. In an alternative embodiment, wavelength division multiplexing is used to create a bidirectional, digitally modulated status channel.

FIG. 3 is a schematic diagram detailing the key node components of a digital reverse transmission system. As shown, an upstream, i.e., reverse, analog RF signal from the return communication distribution system is sampled and converted to an on-off digital format by the analog-to-digital (A/D) converter 300. The data on the parallel output lines of the A/D converter 300 is multiplexed onto a single line by the serializer 305 and processed by an optical transmitter 310, which transmits the digital optical signal upstream within the system via an optical communication channel 315, such as fiber optic cable.

According to a preferred embodiment of the present invention, a status monitoring channel can be added to the digital reverse transmission system as shown in FIG. 4. In this system, the optical transmission from a status requesting device, such as a headend 345 or hub that polls for status information, is converted to an electrical signal by a receiver 340 located within a responding device, such as a node 410 or other device that gathers status information and responds. A directional coupler 335 separates status transmission address information 337 from program information 332. A demodulator 330 converts the address information from a digitally modulated carrier format to a digital bit stream that is coupled to the address input of the transponder CPU 325. Status inputs 328 that include digitally coded information related to device operating parameters are also provided to the CPU 325. Upon receiving its address code from the upstream device 345, a digital output indicative of device parameters is produced by the CPU 325.

In the reverse direction, RF information from other system components is received and digitized by an A/D converter 300, which is coupled to one input of an interleaver 320. The output from the CPU 325 is coupled to a second input of the interleaver 320, which temporally multiplexes the two inputs to generate outputs that are multiplexed by the serializer 305 onto a single line. The serializer output is coupled to the input of an optical transmitter 310, which converts the received digital electrical signal to a digital optical signal 350 that is transmitted via fiber optic cable to an information processing device. The information processing device can be, for instance, the same status requesting device 345 that initially polled the responding device 410. By way of example, the information processing device can be a headend, a hub, another node, or any other device capable of performing actions based on the received status information.

FIG. 5 depicts components of an information processing device, such as a headend station 345 or hub, that receives the return path signal 350 transmitted by the node 410 (FIG. 4). In the processing device 500, which is likely upstream in the communication system from the responding device 410, the digital reverse signal 350 is converted to a digital electrical signal by the optical receiver 450. The receiver output is demultiplexed by the deserializer 455, and its multiple output lines are coupled to a deinterleaver 460. The deinterleaver 460 provides status information on one set of outputs 462 that are coupled to the status monitoring computer 470. Another set of outputs 464 containing digital data originating from subscriber equipment is coupled to a digital-to-analog (D/A) converter 465. The analog electrical signal generated by the D/A converter 465 can then be processed by other system equipment or transmitted to external devices and systems, such as external service provider networks.

In the status monitoring path, the digital output of the status monitoring computer 470 is converted to an appropriate digitally-modulated-carrier format by the modulator 475 and combined with data transmissions 478 by the directional coupler 480. The combined signals are transmitted by the optical transmitter 485 as lightwave, or optical, signals over an optical communication medium.

When compared to prior art systems utilizing AM modulation, the digital reverse system of the present invention offers improved linearity and signal-to-noise performance at lower cost. Specifically, cost reductions can be achieved by replacing the modulator and demodulator in the conventional node-to-primary hub return channel with less expensive interleavers and deinterleavers.

In the alternative embodiment shown in FIG. 6, a bidirectional digital channel is created by using different optical wavelengths for communication in the forward and reverse directions along a single fiber. In the reverse direction, Internet communications, program requests, and other subscriber-generated information enter a responding device 505, such as a node or hub, as RF signals from subscriber devices and other upstream system components. An A/D converter 510 translates the data into a digital word that is forwarded to an interleaver/deinterleaver 515. A second input of the interleaver/deinterleaver 515 is generated by the transponder CPU 520. The transponder CPU 520 generates an output typically comprising a summary of the data provided by the CPU via status input lines 522. The output of the interleaver/deinterleaver 515 is serialized by the serializer/deserializer 525 and

transmitted by an optical transceiver 530 to the information processing device 550 over an optical communication channel 545 at a first wavelength, λ_1.

At the requesting/processing device 550, which may be a headend station or hub, the received optical signal at wavelength λ_1 is converted to an electrical signal by the transceiver 555, the output of which is connected to a serializer/deserializer 560. In the reverse path of the device 550, a single input line of high-speed data is deserialized into several lines at a lower speed, which are coupled to an interleaver/deinterleaver 565. The interleaver/deinterleaver 565 separates the status information provided by the transponder CPU 520 from the program information contained in the signal and transmits the status information to the status-monitoring computer 570 for processing. The other information is provided to the D/A converter 575.

In the forward, or downstream, direction of the communication system, the output of the status monitoring computer 570 is connected to the interleaver/deinterleaver 565, which multiplexes the incoming information, including transponder address information, onto a single, higher-speed data line. This line is connected to the input of the serializer/deserializer 560, which serializes the information and provides it to the optical transceiver 555. The transceiver 555 transmits an optical signal at a second wavelength, λ_2, to the responding device 505. At the responding device 505, the optical signal is converted to a digital electrical signal by the transceiver 530, deserialized by the serializer/deserializer 525, and deinterleaved by the interleaver/deinterleaver 515. Transponder addresses are provided by the interleaver/deinterleaver 515 to the transponder CPU 520, which, if addressed, subsequently transmits status data back to the information processing device 550, as detailed previously.

In this embodiment, the modulators and demodulators of the prior art status monitoring system are replaced by interleaver/deinterleavers and optical transceivers that are designed for bidirectional communication at a number of discrete wavelengths, i.e., wavelength division multiplexing.

In summary, both of the digital status monitoring systems described above provide status information from a first device, such as a device located downstream within a communication system, to a second device using digital, rather than analog, signal formats. As a result, the digital status monitoring systems of the present invention are more reliable and less expensive than prior art systems based on AM modulation.

What is claimed is:

CLAIMS

1. A broadband communication system having a reverse path over which reverse, upstream signals are transmitted and a forward path over which forward, downstream signals are transmitted, the broadband communication system comprising:

a requesting device for generating and transmitting a downstream digital optical signal comprising a status request and information;

a responding device coupled to the requesting device for receiving the downstream digital optical signal and decoding the status request therefrom, for processing the status request in its digital format and gathering digital inputs indicative of requested statuses, and for transmitting an upstream digital optical signal comprising at least status information indicative of the requested statuses; and

an optical communication channel coupled between the requesting device and the responding device for transmitting the downstream digital optical signal and the upstream digital optical signal.

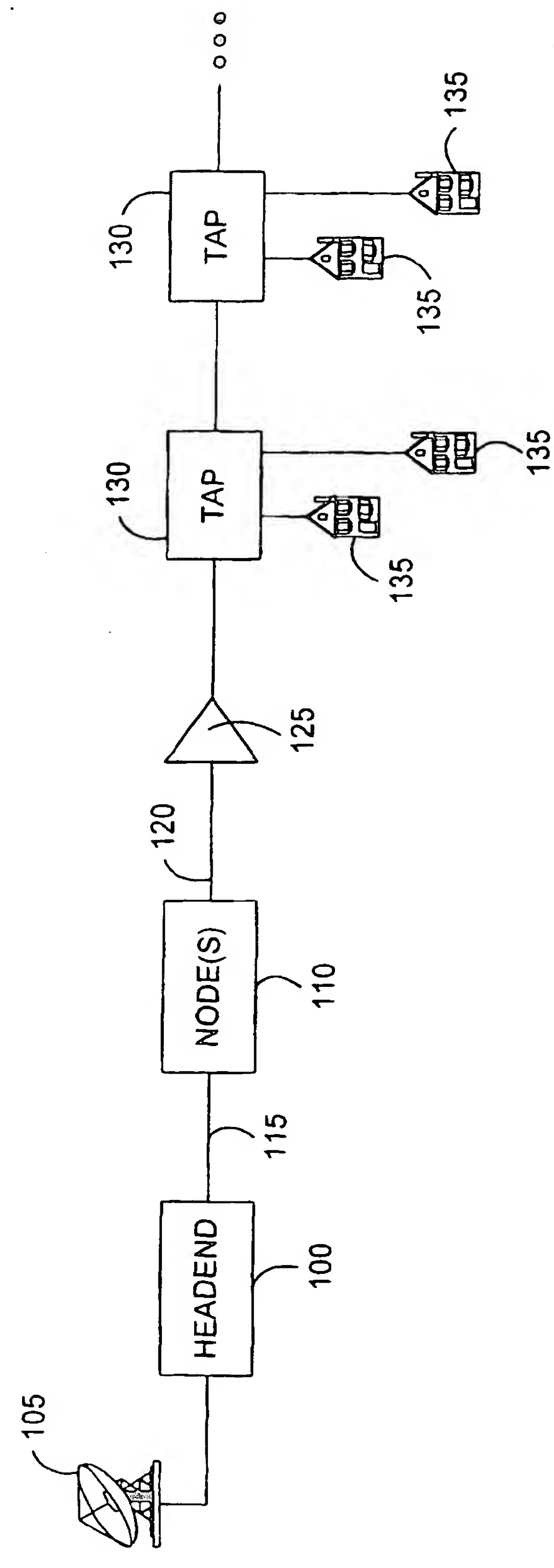
2. The broadband communication system of claim 1, wherein the requesting device comprises headend equipment for transmitting video signals, audio signals, and data, and the responding device comprises one of a node and a hub for further distributing the video signals, audio signals, and data throughout the broadband communication system.

3. The broadband communication system of claim 2, wherein the responding device includes a port for receiving upstream, reverse radio frequency (RF) signals from subscriber equipment.

4. The broadband communication system of claim 3, wherein the upstream digital optical signal includes the status information and the upstream, reverse RF signals from the subscriber equipment.

5. The broadband communication system of claim 3, wherein the responding device processes the status request without converting it to an analog format.

6. The broadband communication system of claim 3, wherein the requesting device processes the status information without converting it to an analog format.



PRIOR ART

FIG. 1

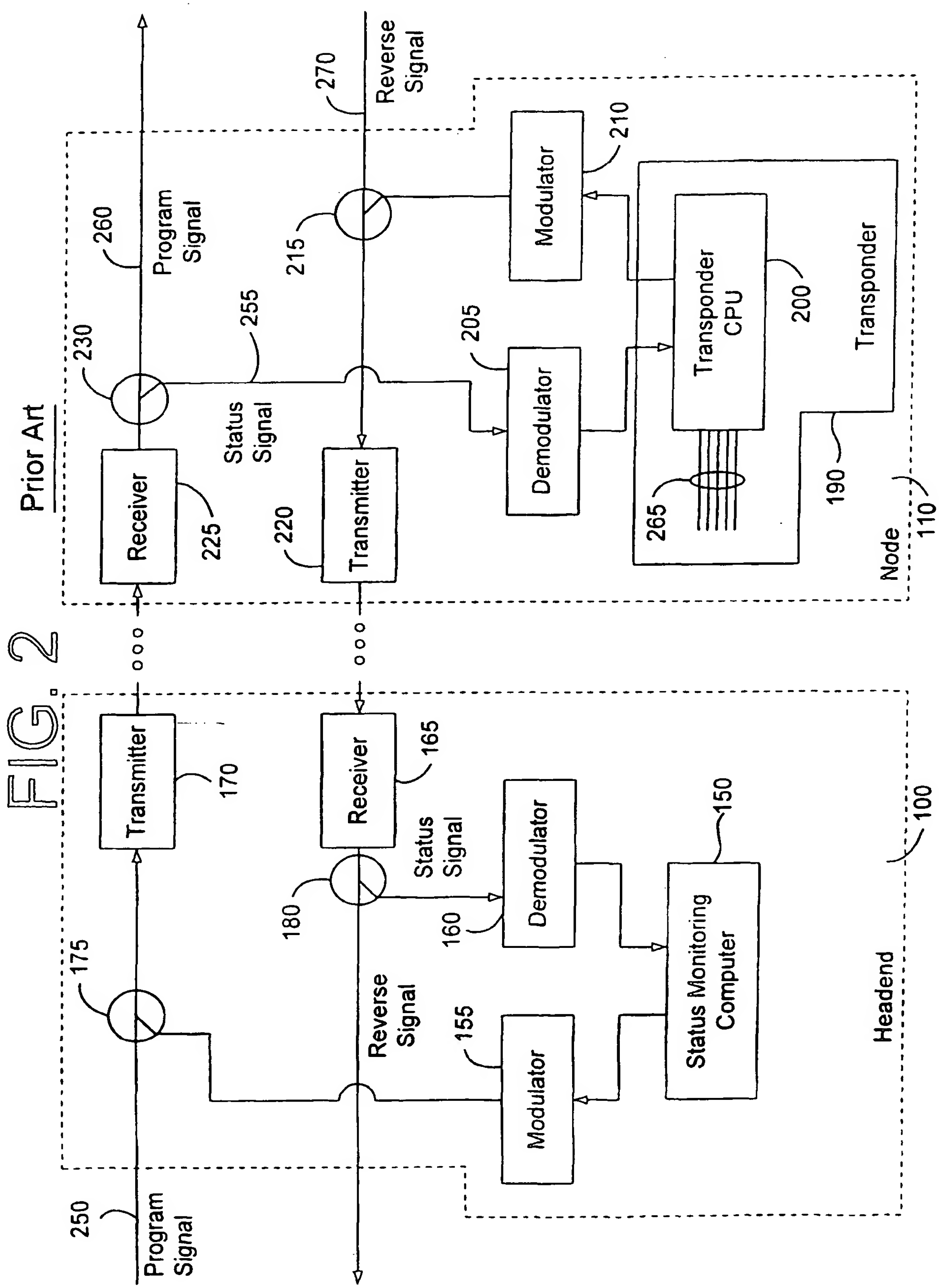

Prior Art
Program Signal
260
Reverse Signal
270
230
Receiver
225
255
Status Signal
215
Transmitter
220
205
Demodulator
Modulator
210
Transponder CPU
200
Transponder
265
190
Node
110
Transmitter
170
Receiver
165
Status Signal
Demodulator
150
Status Monitoring Computer
160
180
175
Reverse Signal
155
Modulator
Headend
100
250
Program Signal

FIG. 2

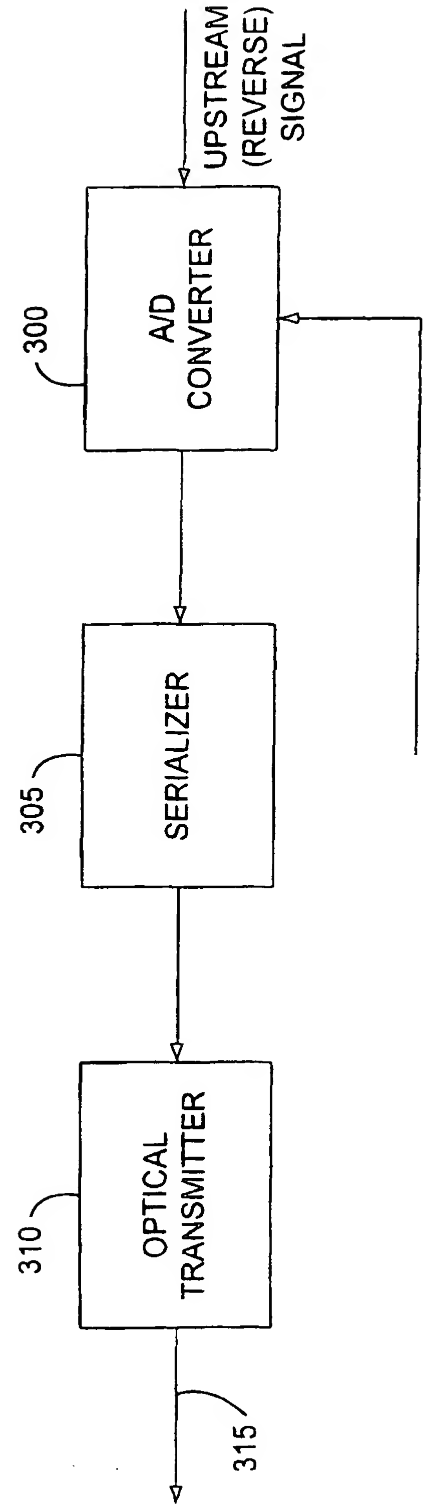

UPSTREAM (REVERSE) SIGNAL
A/D CONVERTER
300
SERIALIZER
305
OPTICAL TRANSMITTER
310
315

FIG. 3

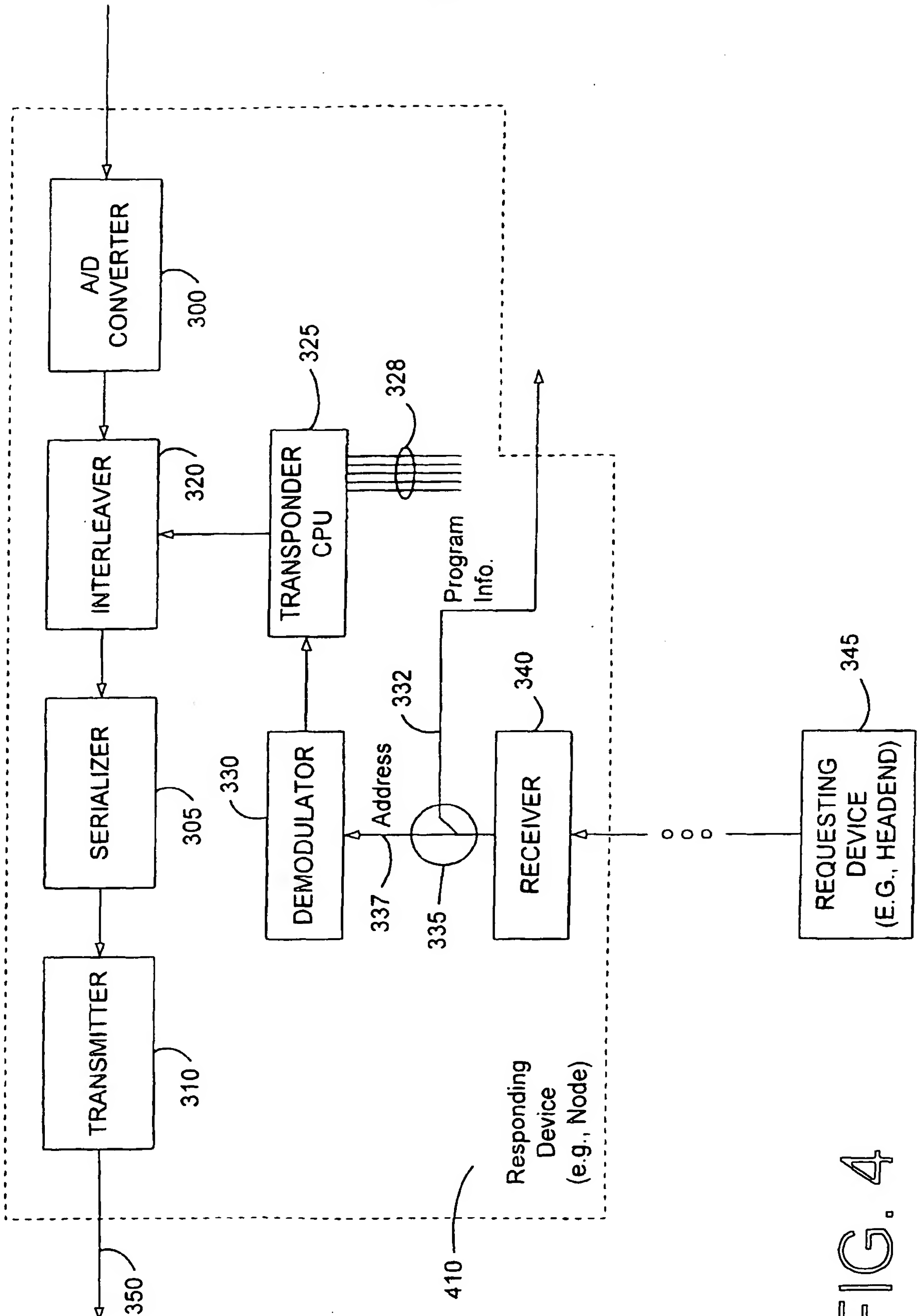
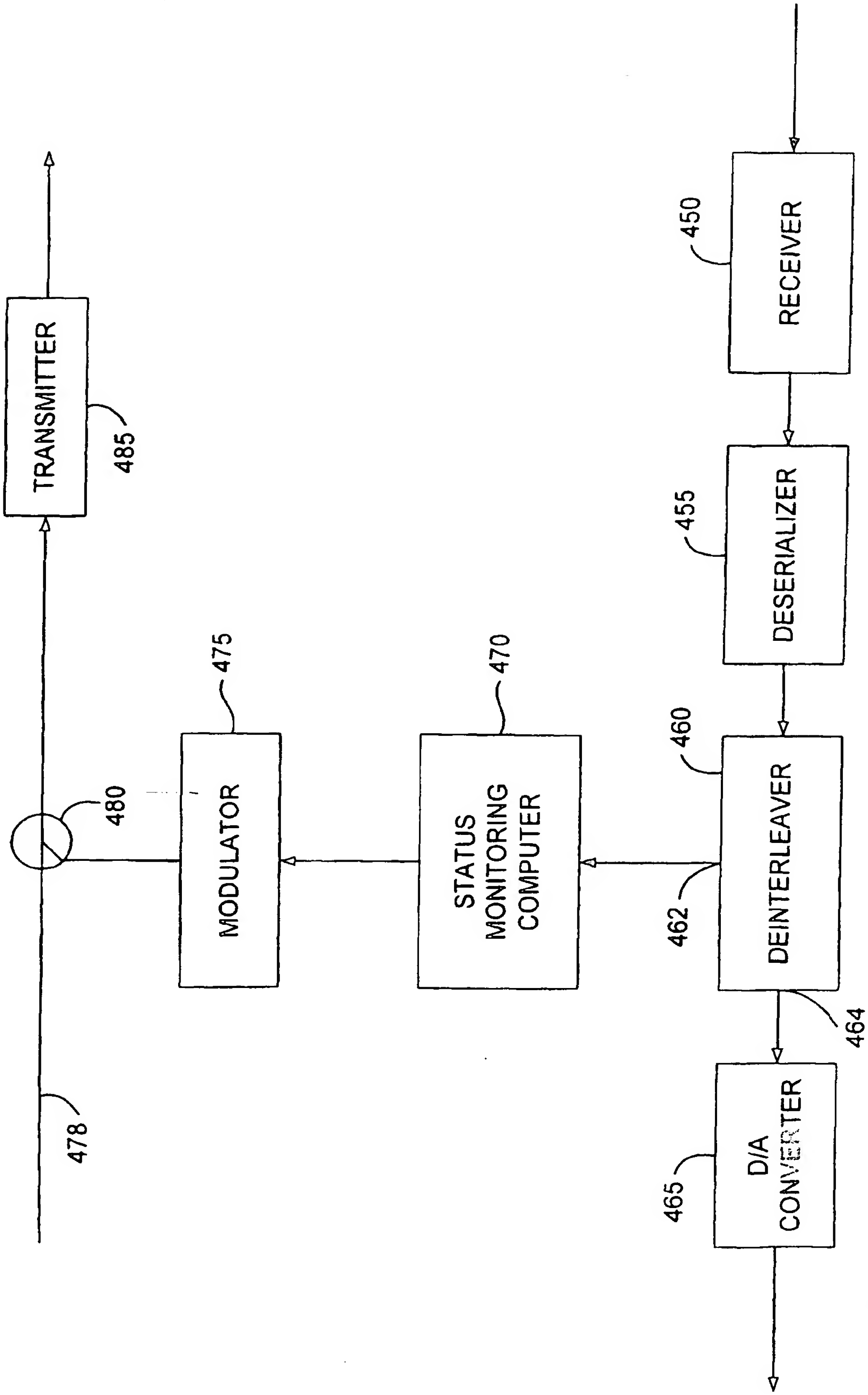

A/D CONVERTER
300
INTERLEAVER
320
SERIALIZER
305
TRANSMITTER
310
350
TRANSPONDER CPU
325
328
DEMODULATOR
330
Address
337
335
332
Program Info.
RECEIVER
340
REQUESTING DEVICE (E.G., HEADEND)
345
Responding Device (e.g., Node)
410

FIG. 4


TRANSMITTER
485
RECEIVER
450
DESERIALIZER
455
MODULATOR
475
480
STATUS MONITORING COMPUTER
470
DEINTERLEAVER
460
462
464
D/A CONVERTER
465
478

345

FIG. 5

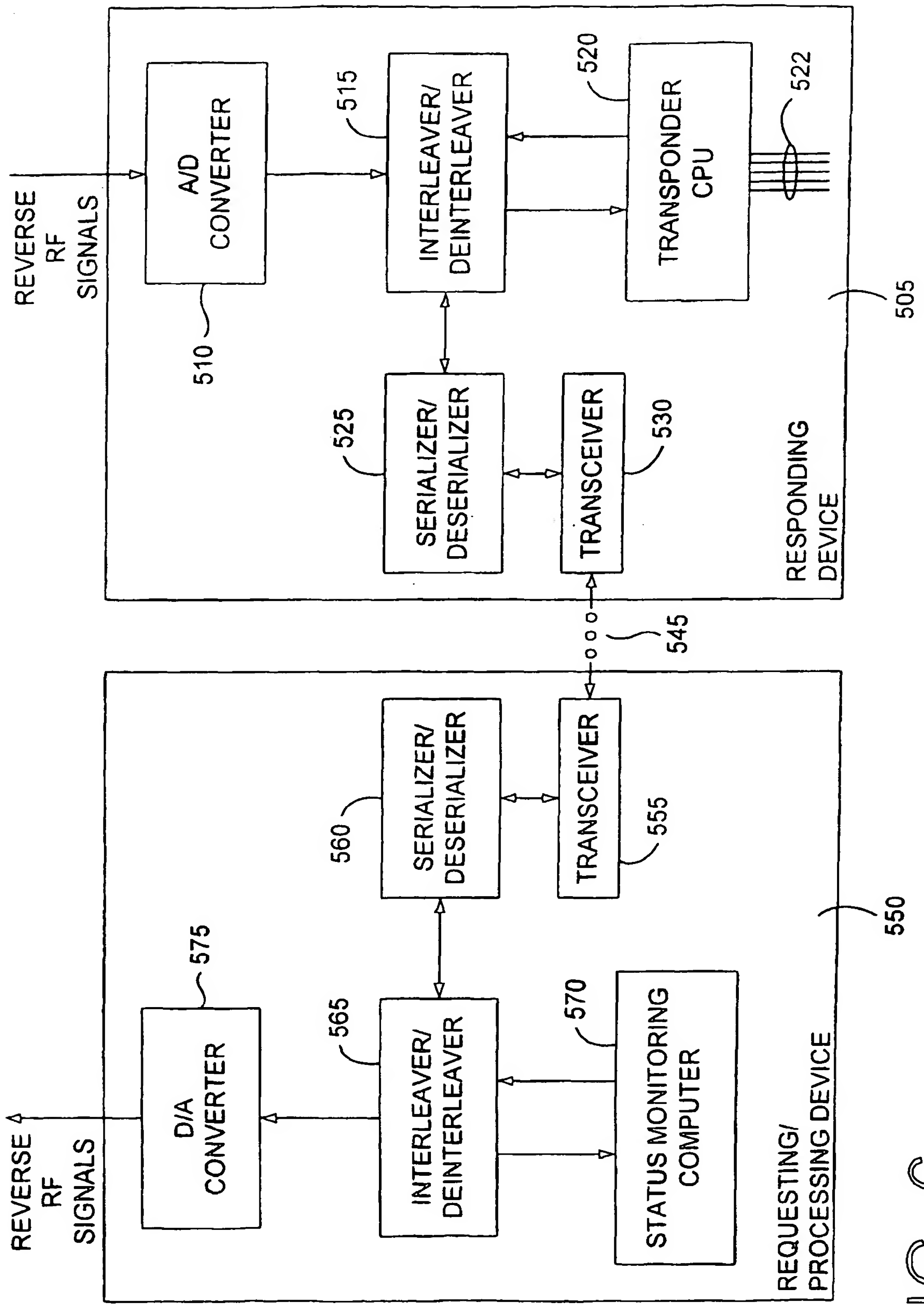

REVERSE RF SIGNALS
A/D CONVERTER
510
INTERLEAVER/ DEINTERLEAVER
515
520
TRANSPONDER CPU
522
SERIALIZER/ DESERIALIZER
525
TRANSCEIVER
530
RESPONDING DEVICE
505
545
SERIALIZER/ DESERIALIZER
560
TRANSCEIVER
555
550
REVERSE RF SIGNALS
D/A CONVERTER
575
INTERLEAVER/ DEINTERLEAVER
565
570
STATUS MONITORING COMPUTER
REQUESTING/ PROCESSING DEVICE

FIG. 6

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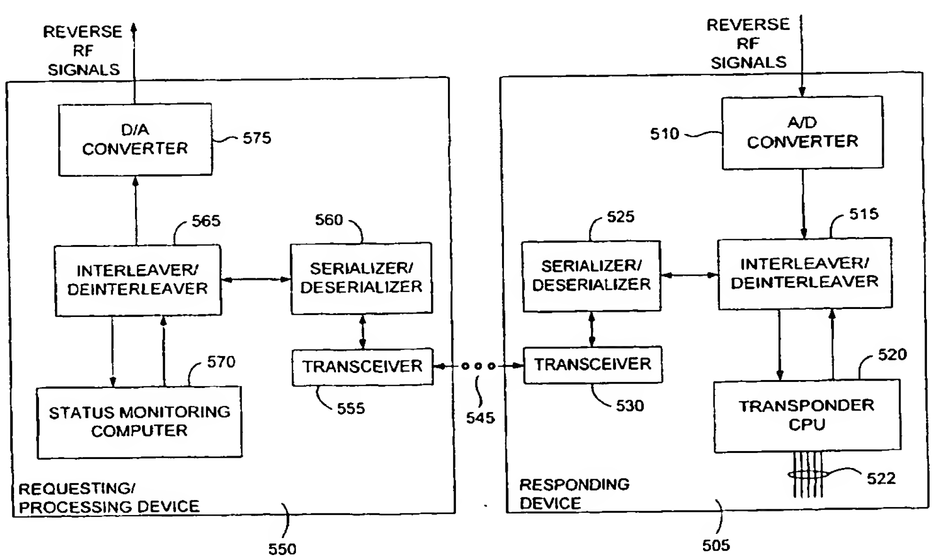

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INTERNATIONAL SEARCH REPORT

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A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04B10/08 H04B10/207 H04N7/22 H04N7/173

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04B H04N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 93 05619 A (SCIENTIFIC ATLANTA) 18 March 1993 (1993-03-18) page 5, line 12 -page 6, line 22; figures 1,2,4 ---	1-4
X	TWU D ET AL: "A novel MAC protocol for broadband communication over CATV-based MANs" COMPUTER COMMUNICATIONS,NL,ELSEVIER SCIENCE PUBLISHERS BV, AMSTERDAM, vol. 19, no. 11, 1 September 1996 (1996-09-01), pages 888-900, XP004052774 ISSN: 0140-3664 page 3, right-hand column, paragraph 3 -page 4, left-hand column, paragraph 3; figures 2,6 --- -/--	1,2

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"A" document defining the general state of the art which is not considered to be of particular relevance

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
8 August 2001	20/08/2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Cochet, B

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 01/02460

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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1

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

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Information on patent family members

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